A COMPENDIOUS STATEMENT

OF THE NATURE AND COST

OF CERTAIN

SEWAGE PROCESSES

BY

MAJOR-GENERAL SCOTT, C.B., F.R.S.

"We must ever bear in mind that whenever success does not attend a good cause, the fault lies in want of energy in using the proper means; for these are always to be found."—*Liebig.*

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CHAPTER I.

Introductory.

"I feel that the most important step towards progress will be made when the public mind is sufficiently disabused of the present exaggerated notion of the agricultural value, in a practical point of view, of highly-dilute Sewage water."—*Dr. Gilbert.*

Q. "May I take it, therefore, that you lay it down before the Committee that the proper way of dealing with the Sewage would be, in the first place, some chemical process of defecation to separate the suspended matter and some portion of the matters in solution, and then use the land as a filter for further purifying the Sewage?"—*A.* "I believe that is the right thing to do."—*Dr. Letheby.*

"The chemical precipitation of the sedimentary matter, which is of very little agricultural value, removes the impediment in the application of Sewage to the land."—*Dr. Voelcker.*

"Very foul waste liquors from woollen dye works can be efficiently purified by intermittent filtration through earth, at the rate of about one gallon per cubic yard of earth per twenty-four hours. But this is a very slow rate of filtration; and we expressed a hope that it might be considerably accelerated by mixing the liquor with a small quantity of slaked lime before allowing it to flow upon the filters. This anticipation has been realized; and we have been able, as the following analytical results show, to purify approximately six times as much of the limed as of the unlimed liquor per cubic yard of earth."—*Rivers Pollution Commissioners.*

"The existing plan of Scavenging is, in fact, an utter failure agriculturally."—*Rivers Pollution Commissioners.*

The object of this pamphlet is to furnish to town authorities and to Sewage Companies information by which to judge of the applicability to their requirements of the processes advocated by Scott's Sewage Company. It affords the means, therefore, of comparing the results to be expected from these processes for dealing with Sewage with those of the simplest and cheapest schemes which have become the property of the public. The quotations at the head of each chapter indicate with sufficient precision the principles on which these processes are based.

It may be safely asserted, that whatever may be the sanitary aspects of the different modes of collecting and disposing of excretal matters, the final cost to a community will—other conditions being equal—vary with the bulk of the inert substances, whether ashes, earth or water, with which the fertilizing elements are mixed in order to render them inoffensive and capable of carriage.

When the dilution is excessive, as in the case of the water-carriage system as practised in this country, every scheme yet devised for purifying the foul water has (so far as can be gathered from published reports) occasioned loss to the town or company which has adopted it. In towns, also, in which the cesspool system is in use, and the excretal matters are mixed with the ashes, the sums derived from their sale have fallen far short of the expense incurred in their removal. Although it is possible, by a rational mode of treatment, to render undiluted excreta harmless, and, indeed, profitable to towns, such a result is not so easily attained after the fæcal matters have been mixed with large volumes of water; but even in this case, by combining the preparation of phosphatic manures with the clarification of the Sewage it may often be possible, in large water-closet towns which can support the cost of a manufacturing process, to cover at least the expenses of dealing with the Sewage.

It is impossible, however, even though all excretal matters be excluded from the sewers, for a large number of people to live in close proximity to each other without fouling an amount of water the disposal of which will become a serious difficulty; but *if proper advantage be taken of the fertilizing elements of the night soil and urine* for the production of concentrated manures, the cost of cleansing the fouled water of the town will not only be covered, *but a considerable profit* may be realized in aid of the local rates.

CHAPTER II.

The Removal of Suspended Matters by Subsidence.

"It is because, in my judgment, Sewage irrigation cannot be carried out from the utilization point of view without storage tanks, that it becomes necessary to deal in some way with the sludge, because if you store, you cannot avoid deposition. I am prepared to go further, and say that as irrigation with Sewage containing the whole of the sludge causes much more smell than irrigation with Sewage out of which the whole or a portion of the sludge has been taken, there are many situations where the extraction of the sludge ought to be compulsory, simply because in a country thickly studded with villas and country houses, I do not think that any man has a right to offend the noses of his neighbours."

"When it (the sludge) is allowed to stagnate and decompose, it stinks worse than anything I ever smelt out of Constantinople."—*Mr. William Hope, V.C.*

It seldom happens that the method of simple deposition of the suspended matters can be resorted to for the clarification of Sewage water in the neighbourhood of large towns. Without chemical treatment of the Sewage, the suspended matters are very imperfectly removed, and the effluent from the depositing tanks retains its offensive smell. Unless, also, the decomposition of the sludge which collects in the bottom of the tanks be checked, an intolerable nuisance is created.

It is not denied that fresh Sewage can, if proper care be exercised in applying it, be run over light and sandy soils without creating a nuisance, but in practice due precaution can rarely be enforced. It will always be advisable, at all events, to deodorize the sludge if produced in large quantities; and as it has a theoretical value of £2 to £4* per ton,

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* The value of the suspended matters will vary greatly with the amount of traffic in the town, with the care exercised in cleansing the streets and the mode in which their surfaces are maintained. Wood or asphalte will give less detritus than stone, and stone-paving far less than

it is an object, at the latter value, at least, to maintain and increase its fertilizing properties.

The mode of treatment which we adopt in such a case is as follows:—The deposit when it has been pumped from the tanks, or removed by means of an Archimedean screw, is thrown into a tank fitted with agitators, and a sufficient quantity of milk of lime is added to destroy all disagreeable smell. A solution of phosphorite, phosphate of iron, coprolites, or bones, in hydrochloric acid, is next added to the mixture in sufficient quantity to make it about neutral to test paper. The resulting mixture is then collected, dried and ground to a powder for manure. In this condition (if the amount of road detritus which finds its way into the sewers is small) it may have, owing to the addition of the precipitated phosphate, a theoretical value of £4 5*s* and upwards per ton. By adding to the sludge a larger quantity of lime and of solution of a low priced phosphate, the value of the dry manure may even be increased to £5 or £6 per ton, and at this price it would command a ready market.

The cost of the process for a town of 100,000

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macadamized roads. An average of the experiments made by the Rivers Pollution Commissioners and of those made by Dr. Letheby on the Sewage of Banbury, Bedford, Carlisle, Croydon, Hertford, Leicester, Northampton, Norwood, Rugby and Worthing, the total quantity of suspended matters was 14·05 grains per imperial gallon, of which 5·34 grains were mineral and 8·71 organic. Taking, however, the results of all the experiments made on Sewage throughout the country, the total quantity of the suspended matters is about double this quantity, and the proportion of organic and mineral substances about equal; but the bulk of these experiments have been made with the Sewage of the largest and busiest towns, viz., London, Liverpool and Manchester. It would, doubtless, when the proportion of mineral matter is so great, be possible to make a separation of some of the grosser siliceous particles, and thus increase the percentage of nitrogen. Unless the percentage of the nitrogen can be made to reach 2½ per cent. the process described in this chapter is hardly worth carrying out in water-closet towns, as the manure then becomes too feeble to find a market. In cesspool towns even feeble manures may be worked in with the night soil with advantage.

inhabitants, the Sewage of which contains a moderate quantity of detritus, is as follows :—

Cost of 200 tons of lime, at 15*s* per ton	£150
Cost of bringing into solution 100 tons of phosphoric acid, at £15 per ton	1,500
Manipulation of 18,000 tons of sludge and its concentration to 1,800 tons of dry manure, at 15*s*	1,350
Interest on a capital of £3,000 for stores, machinery, &c., at 10 per cent.*	300
Expenses of dealing with the deposit	£3,300
Value of 1,800 tons of manure at £2, being less than half the theoretical value	£3,600
Balance in favor of town	£300

Should the "separate system" come into use, as it ought, and this detritus be altogether excluded from the pipes which carry off the water-closet Sewage, the balance in favor of the town would be much better than this; but, even with matters as they stand, it would seem that wherever the amount of detritus in the Sewage is small and there is a moderate local demand for phosphatic manure, the sludge can be got rid of without nuisance and without cost to the town. The effluent from the depositing tanks, however, though much more harmless than when mixed with the solids, is far less clear and inoffensive than Sewage which has been chemically treated. Consequently, unless this process is followed by irrigation or Dr. Frankland's intermittent downward filtration, the evils of Sewage pollution are somewhat mitigated by it, but no more. In short, chemical precipitation is in most cases expedient, and in many absolutely necessary, as a preliminary measure to cleansing by earth.

* The cost of tanks is omitted, as they are essential without reference to the process of treating the sludge here recommended. See the quotations from Mr. Wm. Hope at the head of the chapter.

CHAPTER III.

The Lime Method of Precipitation.

"Sewage run upon land without being previously defecated by chemicals will be a nuisance wherever it is put on."—*Dr. Letheby.*

"Of all the disinfecting methods which have yet been proposed, I believe that which is known as the lime process is by far the most practicable and effective on a large scale."—*Dr. J. H. Gilbert.*

"In a sanitary point of view, the careful precipitation of Sewage with lime has undoubtedly been very successful, although it has not been found profitable commercially."—*Dr. Letheby.*

"I should prefer to treat it with lime alone."—*Dr. Frankland.*

Q. "You think that the milk of lime is sufficient?"—*A.* "Yes."—*Dr. Odling.*

"The lime process does effectually remove this solid suspended matter, and in so far accomplishes a great and manifest good. It also destroys the influence of the noxious gases of Sewage, and . . . . we are of opinion that wherever this (clarified) liquid (Sewage) is thrown into a body of water considerably larger than itself no evil results will practically be experienced."

"This very simple process offers as much prospect of commercial advantage, in respect to the manufacture of solid manure from Sewage, as any patent process which has yet been proposed."—*Royal Commission on the Sewage of Towns.*

The correctness of the last of the observations which stand at the head of this chapter has been abundantly illustrated in the history of the various Sewage schemes which have been tried and successively abandoned. No town undertaking the treatment of its own Sewage thinks of adopting any other than the lime process. It is possible, indeed, by combining a manufacture of precipitated phosphates with the clarification of the Sewage, to prepare a more salable compound, and even show a profit on the combined result, as will hereafter appear; but up to the present time lime has practically answered every purpose, *as a precipitant*, which has been fulfilled by the more expensive compounds which have been sometimes employed in conjunction with it.

Should the recommendation of the Select Committee of the House of Commons on the Birmingham Sewerage Bill (viz., that "no Sewage be put upon any land without having been previously defecated in tanks,") be ever so dealt with as to become an easily enforced law, and irrigation or intermittent downward filtration be made compulsory in the case of towns which throw their Sewage into small streams, the use of the lime process will meet with rapid extension. We therefore here introduce the cost of this plan, and this is the more advisable as the processes advocated in this pamphlet are based upon it.

Cost of the ordinary lime process when efficiently carried out on Sewage of average strength,* from a population of 100,000 :—

Materials and labour, &c.—	
1,860 tons of quick lime, at 15*s* per ton......	£1,395
† Annual expenses of treatment of 4,000,000 gallons of Sewage per diem	1,205
Cost of clarifying and deodorizing Sewage	£2,600

or 6¼*d* per head of the population.

The chief difficulty connected with precipitation now arises. By the use of the precipitant the deposit, though it is in a condition in which it can be more readily made portable, has been increased in volume threefold.

Though, also, the deposit thrown down is at first harmless, decomposition, which is for a time

* Forty gallons per head is assumed as the ordinary dry weather flow.

† The capital for building the tanks and providing the plant is omitted. In all probability the majority of the towns of this country, whether midden or water-closet towns, will be compelled after this Session of Parliament to provide depositing tanks, and as the amount which will be expended upon them will vary not only with the nature of the locality, but also with the style of workmanship which the towns may think it necessary to adopt, no estimate is taken for tanks, except in cases in which the modification of the process requires more tank accommodation than would be needed for simple subsidence.

checked by the lime, again sets in, and the stench becomes intolerable. Hence the necessity of getting rid of it at once, either by disposing of it to the farmers, or by burying it, or else by drying it. The latter treatment will render it perfectly inoffensive for any length of time. In small places of 5,000 or 10,000 inhabitants it may be mixed with town ashes (which somewhat mitigates the nuisance arising from decomposition), and be sold to the farmers, who, at slack seasons for their horses, will pay 1*s* per ton for it and cart it away at their own cost. But in large towns of 50,000 or 100,000 inhabitants it is impossible to find customers within a sufficiently narrow radius of the works to consume so large a bulk of feeble manure. In a town of 100,000 inhabitants the quantity of sludge produced annually, in the condition in which it has to be removed from the tanks, averages about 52,000 tons. This, by running off the water which will separate from it by drainage, may be reduced to about 30,000 tons, having a theoretical manurial value of 5*s* to 8*s* per ton, but it will be in a condition not readily spread on the land, and not worth cartage to a distance. As farmers, therefore, have so little inducement to take it away, it must, unless it can be buried in land near the works, or be manipulated into a more portable compound and one better adapted for agricultural purposes, be removed at the expense of the town. It would not be safe to estimate the cost of pumping and manipulation at less than 3*d* per ton, nor of loading and carriage at less than 2*s* 3*d* per ton, and perhaps 1*s* 6*d** per ton of this outlay might be recovered from the farmer.

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* Stable dung, which has a theoretical value of 13*s* to 15*s*, realizes from 3*s* to 5*s*. This is a high percentage of the theoretical value for so

The cost of disposing of the sludge in this manner would therefore stand thus :—

52,000 tons pumped into drainage pits and reduced to 30,000 tons, at 3*d* per ton......	£650
30,000 tons loaded and carried, at 2*s* 6*d* ...	3,750
	£4,400
Deduct the amount realized by the sale of the same, at 1*s* 6*d*.............................	2,250
Probable cost to the town	£2,150

or rather more than 5*d* per head of the population.

The cost of digging it into the ground,* without considering the question of any other use for the land, would amount to much the same sum as this :—

52,000 tons pumped into drainage pits and reduced to 30,000 tons, at 3*d* per ton......	£650
30,000 tons dug into the soil and buried, at 1*s*	1,500
Probable cost to the town	£2,150

weak a manure, owing to the "potential" condition of its fertilizing elements. The mixture of night soil and ashes of the towns of South Lancashire and North Cheshire having a theoretical value of about 10*s* 6*d* per ton realizes, on the average, only 5*d*, and rarely realizes 1*s* 6*d*, or one-seventh of the full value of its fertilizing elements.

* The possibility of continuing this process over a series of years on the same land has yet to be demonstrated. The only town which has yet made a trial of the plan is Birmingham, which has also under trial the cement process hereafter described.

CHAPTER IV.

DRY SEWAGE MANURE.

"Of the various chemical methods which have been proposed for removing the sedimentary matter from dilute Sewage, I believe the so-called lime process to be the most efficient known. All the analyses, however, which have yet been published on good authority, of the solid Sewage manure so produced perfectly agree with them as to the small amount of nitrogenous matter which they contain." . . . . "In fact, so small is the amount of valuable manurial constituents shown to be contained in such solid Sewage manures, that they could only be useful if applied to the land in several times as many tons per acre as would be required in cwts. of guano or the pure dry excrements." . . . . "It is obvious that such a manure would, on account of the cost of carriage, command no price at all beyond a very limited distance from its place of manufacture. The fact, indeed, that the price of such a manure has, during the last two or three years been reduced from £2 to £3 per ton to about as many shillings, is a practical corroboration of this opinion."—*Dr. Gilbert* (1857).

"We have already stated our belief that, unless some new process of greater efficiency should be discovered, the formation of a solid manure from Sewage will not be remunerative; that is to say, that the amount realized by the sale of the manure will fall short of the cost of its production. Neither is this to be considered as a condition dependent on want of appreciation of the manure, which time and better information on the part of the consumer will remove; on the contrary, the tendency has been hitherto to put the price above the value which a sound acquaintance with the nature of manures would attach to it. It is even questionable whether, in some instances, any money at all would be given for this deposit, and in considering the practicability of carrying into effect plans for the Precipitation of Sewage we must be prepared for this eventuality."—*Royal Commission on the Sewage of Towns* (1858).

"Experience has warned the manufacturer of these feeble manures that the value indicated by chemical analysis cannot be counted upon in the market. Thus, the Leicester mud is actually sold for 1*s* per ton, although its indicated value is from 15*s* to 17*s*."—*Rivers Pollution Commission* (1870).

THE statements which stand at the head of this chapter are certainly not encouraging, but on this point we shall have more to say in the next chapter. The truth would appear to be that the value of Sewage precipitates has of late years been as unduly disparaged, as it was at first magnified, and probably if the properties of the lime precipitate were better known it would command a sale, in many localities, at prices varying from 3*s* to 8*s* per ton. The theoretical value of the lime compound (when ammonia, as at present, is reckoned at £80 per ton,) ranges from £1 to £2, and the practical value might be taken at one-seventh and one-fifth of these amounts respectively. We understand, indeed, that at the present moment small quantities of the Leicester deposit are actually being got rid of for 2*s* 6*d* and 6*s* per ton. We therefore venture to estimate the selling price at 5*s* per ton, a price to which we believe it would ultimately attain, if it did not command it at the outset.

Estimate of the cost of preparing Sewage manure in a dry powdery condition :—

52,000 tons of sludge pumped into drainage pits and reduced to 30,000 tons, at 3*d* per ton	£650
Drying 30,000 tons, and reducing it to 5,200 tons, in a powdered condition, including bagging and other expenses, at 9*s* per ton dry	2,340
Interest on capital incidental to the manure process—10 per cent. on £4,000	400
	3,390
Deduct value of 5,200 tons of manure at 5*s*	1,300
Cost to the town	£2,090

Or as nearly as possible 5*d* per head of the population.

There is, therefore, from the financial point of view, little to choose between the three plans of getting rid of the sludge; but the last plan obviates the danger of nuisance, and inasmuch as the manure is capable of being preserved, uninjured, until the season when it is wanted by the farmer, it may often command a higher price than that we have assigned to it.

It was to obviate the loss to towns resulting from the above methods of disposing of the sludge of Sewage that the Cement and Agricultural Lime Processes, treated of in the next chapter, were proposed.

CHAPTER V.

The Cement Process.

"In the first place, I am happy to say that no injury would arise to Sewage for the purposes of irrigation from the previous process proposed by Genl. Scott. There is no part of the process which could injure the Sewage for use in that way; and secondly, I am satisfied that the Sewage would be so defecated as to admit of the effluent water being finally purified by the smallest area of land."—*Mr. Wm. Hope, V.C.*

"Economically, the scheme seems to me the most promising of all which have been introduced for the purpose of dealing with Sewage, and throwing down the sludge from it, and then dealing with the solid portion so as to convert it into a useful marketable article."

"I do not think there is any commercial value in the material that will be extracted at Dunton, unless they make it into cement."—*Dr. Odling, F.R.S.*

"I should prefer to treat it with lime alone, and to use the sludge according to Genl. Scott's process, which does not occasion the slightest nuisance."

"That deposit would be first dried and then burnt in kilns, and then transformed into Portland Cement. That appears to me to be the process of dealing with this sludge, which has always been a difficulty. It appears to me that this is the process least open to objection. I think it is very perfect in preventing nuisance."

"I would just say to that portion of the meeting who are not chemists, as to the gases produced in burning the cement, that this process of burning the carbon of the organic matter in the original Sewage converts it into carbonic acid gas, and the only thing that can do harm is the carbonic acid gas; but this mixes with the free nitrogen gas which exists in the atmosphere, and is diffused so rapidly through the atmosphere that at a distance of 100 yards from the kiln it would be difficult to find more carbonic acid gas than is normally there."—*Dr. Frankland, F.R.S.*

Colonel Francis having remarked at a public meeting, "That looking to the deleterious matters contained in the original Sewage, he thought that making cement from these materials for buildings might be injurious to public health," Dr. Frankland stated: "There can be no possibility of injury; all chemists are agreed upon that."

"I wish to bear testimony to the fact that the process of drying and manufacturing the dried material into cement could be carried on in the immediate neighbourhood of the town where the Sewage was obtained without creating the slightest nuisance."—*Dr. Voelcker, F.R.S.*

"I examined them (specimens of the deposits) not merely in regard to their power of being converted regularly into a species of cement, but also with regard to the quality of cement, and I found that it was equal to excellent Portland Cement."—*Prof. Abel, F.R.S.*

Q. "I understand you to say that it (the sludge) was converted into something more solid than that?"—*A.* " . . . It can be converted, by Genl. Scott's process, into a very useful and valuable cement."

Q. "That cement is manufactured out of that sludge so deposited?"—*A.* "Yes; and a very excellent cement it is."—*Evidence by Mr. T. Hawksley, then President of Inst. of Civil Engineers.*

Q. "As to the conversion of it into Portland Cement, what do you say?"—*A*. "That process is carried on by Genl. Scott, at Ealing, and from what I have seen of it, it appears to be an extremely satisfactory process, and I think would be suitable for the Birmingham Sewage."

Q. "Have you formed an opinion as to whether the process was a valuable one and likely to come into general use?"—*A*. "I think it is; I have the very highest opinion of it."—*Mr. Bramwell, C.E., F.R.S.*

"Genl. Scott's plan, as far as I am aware, is certainly the best, and I really hope that it will prove successful, and be adopted in many parts of the country."—*Mr. R. Grantham, President of the Committee on Sewage of the British Association.*

"His process is very simple; does not require any very great outlay; and so far as it goes is thoroughly practical and successful. He professes to clarify the Sewage; to deodorize the effluent water temporarily, and the sludge permanently; and he does it. He also professes to make a very good hydraulic Cement, of any desired strength; and he does it."—*Mr. W. Hope, V.C.*

"He calculated, therefore, that two tons and a-half of this cement would be obtained from a million gallons of Sewage. That would be about a ton for every 10,000 people per day. Well, he did not know what might be the demand for cement, but it did not strike him at first sight as being a very large quantity. Such a quantity might very well be used in building operations."—*Dr. Letheby.*

It is unnecessary to add to the quotations which stand at the head of this chapter any further commendations of the cement process. Amongst those who consider it to be the best plan yet proposed for the disposal of the sludge are the most distinguished of the scientific men who have made the Sewage difficulty their study. Most of the objections, with the exception of those relating to cost, that can be raised against a process of this description are met by statements of a very explicit and authoritative kind. The farmer and the agricultural chemist declare that the effluent is, at least, not injured for irrigation purposes: The chemist states that, after the process, filtration can be carried out on one-sixth of the area required for raw Sewage: Chemists and engineers agree in the fact that excellent cement can be made from the sludge, and that, looking to its small agricultural value, this is the best purpose to turn it to: And all are in accord upon the fact that the process can be carried out without creating a nuisance. The opinions, too, of these eminent men have been confirmed by experience at Birmingham and elsewhere. It therefore only remains for us to give the estimate of the actual cost of the process. This is as follows:—

52,000 tons of sludge, reduced by drainage to 30,000, at 3*d* per ton	£650	
30,000 tons dried, yielding 5,200 tons of dry material, at 7*s* per ton dry	1,820	
5,200 tons, burned to 2,600, cement, ground and bagged, at 7*s* per ton burned	910	
Interest on £8,000 capital, incidental to cement process, at 10 per cent.	800	
		4,180
Value of 2,600 tons of cement, at 35*s*		4,550
Balance profit......		£370

Or nearly $\frac{9}{10}d$ per head in aid of the rate for clarifying the Sewage.

In other words, the cement process shows an advantage of 6*d* per head, as compared with the other plans which we have previously considered for dealing with the sludge.

The cement process is adapted specially for large towns with a rapidly increasing population. In such cases a ton per week for every 2,000 persons is an amount which could be readily got rid of. The process is manifestly unsuited for places where the yield of cement would be too small to constitute a "manufacture."

The agricultural lime process, which is almost similar to the cement process, (the only difference*

* In small towns where the amount of detritus, or solid refuse, which finds its way into the sewers—is small, clay must be added with the lime in order to make cement. In large towns this has been found to be unnecessary. In Birmingham, owing to the large amount of salts of iron in the Sewage, derived from the hardware manufactures of the town, lime instead of clay has to be added to the precipitate in order to supply sufficient calcareous matter for the production of cement. This is a serious drawback, but it is one which can occur only in two or three other towns in the kingdom.

being the absence of the necessity of grinding in the former,) can be carried out in smaller towns than the cement process, as the dry sludge can be stacked and left to await the period of the year at which agricultural liming is carried on before it is calcined. The operation is, however, manifestly only suitable in localities where liming the land is extensively resorted to; but in such localities, owing to the value imparted to it by the phosphoric acid, the Sewage lime can be more profitably carried than ordinary lime.

The expense of its preparation may be regarded as being a fraction under that attending the manufacture of cement, and the theoretical value of the product as about the same as the value of the cement. In the case of a trial at West Ham, Dr. Voelcker reported that the phosphoric acid in the calcined Sewage deposit increased the value of the ton of lime by "just about £1 in round numbers," and in all the foregoing estimates we have assumed the value of the lime to be 15*s* per ton, making a total of 35*s*, which is the same value as that which we have assigned to the cement. We could not assume in practice, however, a value of more than 30*s* for phosphatic lime for agricultural purposes.

CHAPTER VI.

Improved Calcination and Manure Process.

"If the excrementitious matters were in a dry, portable and non-putrescent condition, like guano and other concentrated manures, on which assumption alone could their constituents be valued by the same tariff. They could, like those substances, be stored for any reasonable length of time. They could be applied to the land at the most fitting seasons, and above all, they would be applicable to almost any crop, and especially to corn."—*Dr. Gilbert, F.R.S., on the Main Drainage of the Metropolis.*

"To sell manure constantly to get it off our hands, and by making the farmer take it when he does not want it and cannot advantageously apply it, we are entirely at his mercy and must accept his prices; but if we could store it, make it into a good manure, and sell it when he wants it, then, and not till then, can we expect to realize its full value."—*Mr. E. C. C. Stanford, F.C.S.*

The processes described in the last chapter are the most obvious and simple when calcination is resorted to in order to dispose of the sludge. For large water-closet towns, the Sewage water of which, owing to heavy traffic and other causes, contains much detritus; and where, moreover, there is a demand either for agricultural lime or for cement, we know of nothing better. In cases, however, in which the proportion of the *organic* suspended matter is large as compared with the suspended *mineral* matter, and where there is a good demand for manures of a character feeble as compared with good guano, but yet sufficiently rich in fertilizing elements to obtain favour with farmers, the process we are about to describe may be confidently recommended. It has also the advantage of being free from the sentimental objections which have been raised to the cement process. The instinct of the unlearned part or majority of mankind is averse to the employment in their buildings of a material derived from such an offensive source as excreta,* and many years will probably elapse before this prejudice, absurd though it be, is conquered. The instinct, also (and one which has reason on its side, so long as a stone is left unturned which will enable fertilizing matter to be utilized in agriculture), of thoughtful men is opposed to the idea of destroying this valuable matter, or removing it from the circulation ever going on in Nature's laboratory. Thus, we find an eminent chemist writing in the *Quarterly Journal of Science:* "The third scheme of getting rid of Sewage, viz., that of destruction, requires only a brief notice. By its very nature it forces us to condemn it . . . For our part nothing will satisfy us but rational utilization. Under the head of destructive processes, we include the lime process of Tottenham and General Scott's process." The reader will doubtless consider that process the most rational which gives most relief to the poor from heavy rates; and it is for this reason that we feel no objection to the mode in which Dr. Voelcker expresses the same idea as the author of the above passage. Dr. Voelcker says: "You have, however, to consider in burning two tons of dried lime sludge in order to gain £1 worth of phosphate of lime, (he alludes to the agricultural lime process,) you lose all the organic matter, and this is worth £2 10*s* † per ton. If you can, therefore, find a

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* See the statement at the head of Chap. V, by Dr. Frankland.

† The nitrogen present in the sample referred to was high. The proportion of nitrogen, of course, depends much on the amount of detritus in the Sewage, and the extent to which the clarification process is carried. If this clarification be made very complete, the quantity of carbonate of lime thrown down is from two to three times the amount of the sedimentary matters.

market for the dried lime sludge, it is evidently bad economy to burn it." Nobody can reasonably dispute so carefully qualified a conclusion as this. The plan we are about to describe, however, almost wholly obviates Dr. Voelcker's objection. Whilst the destruction of organic matter it involves is comparatively small, as much as possible is done to concentrate and add to the fertilizing properties of these sedimentary matters, and render them capable of bearing carriage. It is, in fact, a combination of the process described in Chapter II, and the agricultural lime process described in the last chapter, the calcination of the precipitated carbonate of lime being repeated several times, and the lime so obtained being used and re-used for precipitating fresh portions of sewage.

After having been employed, however, six times and calcined as often, the precipitate becomes so charged with phosphoric and silicic acid, that there is no economy in pursuing the process further, and the lime thus obtained is used to deodorize the deposit arising from the suspended matters. The free lime is then neutralized with phosphoric acid as already described in Chapter II, and the resulting compound is collected and dried for manure.*

The financial results of the process are as follows :—

Cost of labour and materials—

125 tons of phosphoric acid made soluble in hydrochloric acid, at £15 per ton …… £1,875

* In this process no more lime is required than that which is necessary to start the process. At each precipitation there is an actual gain of lime, owing to the precipitation of some of the carbonate of lime in the Sewage, and this gain is so considerable that no provision is made in the estimate for a supply of lime.

Brought forward	£1,875
18,000 tons of sludge treated with 400 tons of phosphatic lime and 125 tons of phosphoric acid, and collected, dried and powdered at 15*s* 6*d*	1,395
Collecting, drying and calcining 40,000 tons of carbonate of lime sludge=4,000 tons of deposit and 2,400 tons of phosphatic lime at 25*s* per ton calcined	3,000
Interest on capital £10,000 at 10 per cent.	1,000
	7,270
Deduct value of lime saved by this process .	1,395
Total cost of conversion of sludge	5,875
Value of 1,900 tons of manure, at £3 10*s* per ton*	6,650
Balance profit to the town...	£775

or upwards of 1¾*d* per head of the population, showing this process to have an advantage of 7*d* per head over the first mentioned manure methods of dealing with the sludge.

By taking advantage of the facilities for the manufacture of a precipitated phosphate of lime, which result from having command over a large volume of limed effluent water, and by mixing the manure so made with the deodorized subsidence matters, a much more valuable and salable compound may be obtained. At the same time, the effluent is considerably improved by the abstraction from it of notable quantities of nitrogen which are removed, either mechanically or chemically, by the precipitate thus obtained. In localities, at all events, in which hydrochloric acid can be obtained at a cheap rate, and be utilized for rendering soluble the phosphatic substance to be employed, this additional process is strongly to be recom-

* The theoretical value is from £4 10*s* to £5. The latter value is sufficient probably to command a market on the results shown by chemical analysis.

mended. It consists, simply, in adding phosphoric acid, which has been rendered soluble, to the effluent from the liming tanks. The additional tanks required would not cause an outlay of so much capital as would at first sight appear, since the effluent from the liming tanks need not be so clear as would be necessary if there were no subsequent process, and the liming tanks may, therefore, be of smaller capacity.

The cost of the process will be as follows:

Materials and labour—

300 tons of phosphoric acid made soluble ...	£4,500
Collecting 20,000 tons of precipitated phosphate and reducing the precipitate to 1,500 tons of dry manure in powder, at £1 per ton ...	1,500
Interest on capital £5,000, at 10 per cent. ...	500
	6,500
Value of 1,500 tons of manure at £5 10*s**	8,250
	£1,750

If the two manures be mixed we shall have a total of 3,400 tons per annum, with a theoretical value of about £6 per ton; and, assuming that this be sold at £4 10*s* per ton, the profit to the town on account of their Sewage and manure works will stand thus:—

Materials and labour—

On account of the deodorization and lime calcination processes ...	£7,270
On the phosphate manure process ...	6,500
	£13,770

* By converting the precipitated phosphate into soluble phosphate the value of the manure would be considerably increased. The theoretical value, without the addition of sulphuric acid, is upwards of £7 per ton. A manure of this price will always command its theoretical value.

Brought forward	£13,770
Value of 3,400 tons of manure at £4 10*s* per ton	15,300
Balance profit	£1,530

or (including every expense but that of liming tanks*) a gain of upwards of 3½*d* per head of the population.

The amount of nitrogen removed in the course of the year by the second precipitation, for a town of the assumed size and conditions, would, probably, be from 200 to 250 tons, and this represents an improvement in the effluent of considerable importance.

The separate and recalcination process of lime treatment is equally useful when the object to be attained is not so much the preparation of a manure as of obtaining a pure effluent by means of sulphate of alumina or a salt of iron. When the limed effluent is treated by one or other of these metallic salts, alumina or oxide of iron is thrown down in a condition readily dissolved by acids, and considerable economy in materials is thus gained, for the only chemical employed after the first few days of precipitation would be the acid for reconverting the alumina or iron into the form in which they can be again used as precipitants.

* The expense of liming tanks will vary from 2*d* to 6*d* per head, according to site and style of workmanship, &c.

CHAPTER VII.

The Profitable Utilization of Excreta.

"Within many of the towns we find the houses and streets filthy, the air fœtid; disease, typhus, and other epidemics rife amongst the population, bringing in their train destitution and the need of pecuniary, as well as medical relief, all mainly arising from the presence of the richest materials of production, the complete absence of which would, in a great measure, restore health, avert the reeurrence of disease, and, if properly applied, would promote abundance, cheapen food, and increase the demand for beneficial labour."—*Sanitary Report General Board of Health*, 1842.

"No one will doubt that if the sanitary requirements of the Nation could be attained by any system which would preserve the excrements of the population free from admixture with water, and present them for use, at once undiminished in value by decomposition, and in a portable innoxious condition, the land of the country devoted to the growth of human food might, by their application to it, be greatly increased in its productiveness."—*Lawes.*

"The existing plan of scavenging is, in fact, an utter failure agriculturally. That which is the especial opprobrium of the water-closet system is almost equally true of the privy and the ashpit. Not one-seventh of the excrement of man is carried to the field; the liquid part drains directly to the sewer or sops the land on which the houses stand, and even the solid part, mixed with the ash waste, with which it is carried to the manure depôt, first receives a washing which soaks most of its valuable parts away."

"It must be borne in mind that the transformation of urea into carbonate of ammonia is attended by the development of myriads of living organisms, chiefly vibrios and bacteria, and they rapidly set up putrefaction in other kinds of organic matter with which the charged urine comes into contact. It is, therefore, obviously a fallacy to suppose that by merely keeping solid excrement out of our rivers the sewage pollution of the latter is prevented." —*Rivers Pollution Commissioners' 1st Report*, 1870.

"It is almost to be feared that guano will play a momentous part in history. . . . . From the enormous increase of the population of London, and other large cities of Great Britain, the loss which the English fields sustain annually in the main conditions of their fertility is every year becoming more and more considerable. . . . In the actual position of English agriculture, America, by her guano beds, rules the prices of all the Corn Markets of Europe, and more especially in England; and should circumstances ever arise to prevent the importation of guano into England, a state of things would ensue in that country of which the consequenees might be incalculable."—*Liebig*, 1859.

It would appear from the above quotations that both the system of collection of excreta from house to house, and the water-carriage system have been conducted in this country in an equally improvident manner, whether regarded from the financial or sanitary point of view. The importance to the nation of this question is, however, scarcely second to the coal question. We are at present largely dependent on supplies of guano for the fertility of our fields. This material, which is being rapidly consumed, now commands double the price at which it was sold a few years since, and the time when the guano beds will be exhausted cannot be far distant. Liebig, with reason, warns us of the folly of thus allowing the productiveness of our country to depend on a supply of foreign manures. He estimates that England consumes nine-tenths of all the guano brought to Europe, and dreads the result for this country if a check should take place in the importation. Yet the amount of recoverable fertilizing elements which we yearly waste (or worse than waste, for they are made to contribute to the pollution of the air we breathe and the water we drink), is quite four times the amount in value of all the guano we import. Whatever may be the merits or demerits of the water-closet system, it would be impossible now to do away with it, but it is perfectly practicable to substitute for the improvident cesspool and midden plan, a rational mode of collecting and disposing of excreta, which would enable us to return to the fields in a concentrated form a large percentage of fertilizers, now absolutely wasted. The object of this chapter is to show how so desirable an end may be attained. The process advocated is based on very simple principles. These are :—

> *First.*—The separation, so far as it can be effected by simple appliances, of the liquid excreta from the solid portions.
>
> *Secondly.*—The deodorization of the solids by deodorants obtainable at a cheap rate, and in a form which will not materially add to what have been termed "profligate associates" of the manure.
>
> *Thirdly.*—The recovery of the ammonia

from the urine, before discharging it into the sewers, by means of a salt which can be readily made to yield up the ammonia thus recovered to a mineral acid, so that the salt can, if necessary, be made to do duty as a carrier of ammonia from the urine to the manure.

Fourthly.—The removal from the fæces, and from the salt of ammonia derived from the urine, of the excess of water present.

On this system, without any excessive care in the collection of urine, a manure worth £10 per ton and upwards may be made from the excreta of a population.

The quantity of excrement voided annually by a population of 100,000* is as follows:—

Amount of fæces		3,246·8 tons
Containing Nitrogen	=	47·8 tons
" Phosphates	=	67·3 "
Amount of urine		42,031·8 tons
Containing Nitrogen	=	376·5 tons
" Phosphates	=	169 "

We assume that four-fifths of the solids can be collected and one-half of the liquids. Therefore of fæces there will be recovered per annum 2,597 tons

Containing Nitrogen	=	38 tons
	=	46 " of Ammonia
" Phosphates	=	54 "
† Value in a finished manure		£4,220

And of urine there will be recovered ...... 21,015 tons

Containing Nitrogen	=	188 tons
	=	228 " of Ammonia
" Phosphates	=	84 "
† Value in a finished manure		£19,500

Or a total both in fæces and urine of £23,720.

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* The table from which these figures are taken is given in the first Report of the Rivers Pollution Commissioners. The data are derived by Röder and Eichorn from the researches of Wolf and Lehman.

† Ammonia taken at £80 per ton, Phosphates in fæces at £10, and in urine at £15 per ton.

The amount to be collected and carried to the factory will be :—

Fæces	2,600	tons, nearly
Urine	21,000	„ „
Total	23,600	„ „

The cost* of the process is approximately as follows :—

ESTIMATE.

Materials—		
800 tons Sulphuric Acid† at £5	£4,000	
40 tons Phosphoric Acid at £45	1,800	
Magnesia, Lime, Charcoal, &c.	750	
		£6,550
Collection 23,600 tons at 4*s*		4,720
Labour—		
Deodorizing and drying 2,600 tons of fæces, and reducing the same to 1,200 tons of manure at 10*s*	600	
Collecting from urine 228 tons of Ammonia, as ammoniacal Phosphate of Magnesia, extracting Ammonia from same with Sulphuric Acid, and drying the resulting compound, 1,300 tons, at £3	3,900	
Mixing, bagging, agency and sundry expenses, 2,500 tons, at £1	2,500	
		7.000
Interest on capital of £12,000, expended upon works and plant at 10 per cent.		1,200
		£19,470

* The estimate is based on the assumption that the collection is made on the sanitary pan system, and that in addition to the urine discharged into the pans with the fæces, one-fourth only of the urine voided at other times (making one-half of the total quantity) is recoverable in vessels placed for the purpose of receiving the chamber slops and in urinals.

The process can be readily applied without the cartage of the liquid to the factory by means of filters of phosphate of magnesia through which the urine from blocks of houses or of whole streets is made to pass before emptying itself into the sewers, but it is thought better, in the first instance, to make as little change as possible in the present mode of collection.

† Hydrochloric acid may be substituted for sulphuric acid.

Brought forward		£19,470
2,500 tons of manure, value in fæces and urine	£23,720	
Value added in Phosphoric Acid.........	1,600	
		25,320
Balance in favour of process		£5,850

Or a profit of about 1*s* 2*d* per head of the population.

To which we may add the present cost of removing excreta at £50 per 1,000 = 1*s* per head of the population, thus giving a total profit of 2*s* 2*d* in favour of the above process.

In every large town, even if worked on a system of complete exclusion of all human excreta from the sewers, there must be a large volume of water polluted, and this ought to be cleansed before it passes into rivers. Towns will never be worked wholly on such a system of exclusion, for the wealthy will adhere tenaciously to water-closets.

The amount of sedimentary matters at the Sewage outfall will of course be lessened in bulk in proportion as excretal matters are kept out of the sewers, and at the same time the value of the deposit obtained will be diminished. In all cases, however, in which the excreta are collected and treated in the manner above advocated, the resulting manure will be sufficiently concentrated to admit of a considerable admixture of feeble fertilizers without detracting from the practical value of the manurial elements, as determined by analysis.

In the case already taken (*see* page 26), we will suppose that the theoretical value of the compound obtained from the liquid Sewage is reduced to £3 per ton; we shall then have—

1,900 tons of manure at £3	....	£5,700
2,500 „ „	....	25,320
4,400		£31,020

Or about £7 per ton.

A price which commands a very ready sale at the theoretical value.

The result to the town, supposing that the manures were sold at £6 10*s*, would stand thus :—

Expenses entailed by dealing with liquid Sewage	£7,270
" " " " Excreta	19,470
Total	£26,740
4,400 tons of manure at £6 10*s* per ton	28,600
Balance profit to the town	£1,860

That is to say, by dealing with the whole of the fæcal matters and foul water of a large town on a rational system of concentration, instead of one of degradation, of the fertilizing elements they contain, its inhabitants will not only be relieved from the cost to which they are at present put on this account, but be benefitted to the extent of nearly 4½*d* per head of the population per annum. Moreover, the country would be made independent of foreign fertilizers, a stoppage in the supply of which would be a serious catastrophe. "It is almost to be feared," says Liebig, "that guano will play a momentous part in history. . . . . Bloody wars have sometimes sprung from causes of much less importance."